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Computer simulations provide powerful models for establishing goals, guidelines, and constraints in educational planning. They are dynamic models that allow planners to examine logical descriptions of organizational behavior over time as well as permitting consideration of the large and complex systems required to provide realistic descriptions of behavior processes. Four types of simulations are particularly applicable to educational planning. Descriptive simulations provide models of human systems that explain their behavior and can be used to test theories by comparing real past behavior with simulated behavior. Intellective simulations capture organizational qualities deemed important by the analyst and are suited to discovering the effects of proposed changes. Normative simulations are designed for analyzing such organizational problems as communications difficulties, social interaction patterns, hierarchical structures, and the implications of various strains and stresses. Finally, man-machine simulations involve interaction between a human actor and a simulated environment. Their success as management games suggests their relevance to the training of educational administrators. (TT)

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THE USE OF COMPUTER SIMULATION TECHNIQUES IN EDUCATIONAL PLANNING*

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INTRODUCTION

Simulations of organizations or behavioral processes may serve the behavioral scientist in the same way that simulated models have served engineers. Consider the much-used example of the model airplane vis-a-vis the wind tunnel test. The engineer runs scale-model airplanes in wind tunnels to obtain insight into the performance of complicated machinery under real life conditions. Sociologist, psychologist and economist similarly may use small group laboratories to study the nature of human systems and increase our understanding of certain observable behavior.[1]

Computer simulations can provide very powerful models for analyzing certain classes of organizational behavior.[2] Some planning problems involve very complex organizational behavior and, hence, have attracted system analysts interested in advancing the science of computer simulation. Not all planning activity, of course, can be considered fertile territory for computer simulation. In some instances, the planner is confronted with simple computational problems (e.g., forecasting requiring the use of statistical or mathematical techniques) where computerization of calculation is followed to save time or facilitate accuracy. While such data processing is a useful application of computers and is invaluable to large organizations, it does not represent computer simulation.

The purpose of this paper is to briefly sketch some areas in educational planning where computer simulation techniques may make significant contributions. Greater stress will be given to planning problems in higher education not because such organizations are more appropriately the subject of discussion at this time but because the writer can conjure up examples more readily. It should be clear throughout the discussion that the examples are generalizeable.

GENERAL DISCUSSION: PLANNING AND COMPUTER MODELS

As a recognized function, planning has had its greatest acceptance in industrial and governmental organizations.[3] But even there, the evolution and growth has been the subject of more rhetoric than action.

The evolution of managerial and administrative activities started with implementation, the development of ordered and organized ways of getting operating units in organizations to do; added control, those activities related to establishing performance measurement and monitoring the behavior and practices of operating units in light of such standards; and lastly, gave thought to planning as a managerial function separate from implementation and control.[4]

By organizational planning, we mean the process of establishing goals, guidelines and constraints for organizations.[5] For the purposes of showing the usefulness of computer simulation in planning, we might further discuss two conceptual frameworks: strategic and extrapolative.[6] These frameworks in turn imply certain problem

solving approaches. I suggest that computer simulation can make its greatest contribution to strategic planning in education by making it possible to pursue open problem solving more effectively.[7] Let us examine this proposition.

Strategic vs. Extrapolative Planning

The central feature of extrapolative planning is its dependence on past data. The planning analyst starts with historical performance and projects potential sets of activity, given possible changes among factors not subject to the control of the organization. From that potential set of activities, a specific plan is articulated and converted into coordinated action. In contrast, strategic planning starts with the assumption that the major forms of planning activities should be probing and far-ranging analyses of the environment of the organization and non-recurring events. Further contrast and comparison between the two conceptual frameworks of planning can be facilitated by examining the differences in approaches to several key elements in organizational planning: (1) the state of nature, (2) the rationality of the decision-maker, (3) the range of alternatives and outcomes, (4) the relations which facilitate ordering of alternatives and outcomes, and (5) the goals or ends to be served.[8]

State of Nature - By the state of nature, I refer to environment forces, those aspects of the environment that affect the choice of a given plan of action but are not controllable by the organization. Strategic planning assumes that a high degree of uncertainty surrounds such factors and, more than likely, it is not sufficient to project from past experiences without extensive "search" of the many

possible states that the factors may assume. Extrapolative planning assumes that we can predict with some degree of certainty on the basis of past experience how environment forces will affect a given plan and, hence, it is sufficient to assign a weight or value within the context of a probablistic or risk scheme. For example, one can say that the chances are .99 for a "tight" University of California budget under Governor Reagan. Not all forces in the environment of the University are so easily predictable. The more unique the environment forces are for a given situation, the less relevant are past experiences.

The Decision-Maker - Strategic planning provides a more "open" approach to the question of rationality. Decision makers are viewed as humans; they grow and learn how to solve problems by doing and seldom have enough information. The decision rules followed in choice situations are rules-of-thumb with a historical rather than scientific basis. Moreover, decision makers are bounded rationally by their perception of the world around them. In extrapolative planning, the decision maker is assumed to be "delicately skillful in analyzing the whole of a problematic situation." The human qualities of the decision maker are subordinated to certain machine-like qualities of the "organizational" man. To illustrate, take the case of "incremental" university budgeting. In estimating the budget for a future year, a percentage increase (decrease) is added to (subtracted from) the previous year. Such a planning strategy assumes an optimal degree of consistency and objectivity in the decision processes, to say nothing of the limited possibility of changes in the pattern of activity for a given unit. For some

academic units in the university, this may be true. For others, such as student affairs, yesterday's budget reflects activities which are no longer emphasized or accepted by students. There is increasing evidence that the entire university is in a period of change where goals and activities in departments are more related to future aspirations than the norm established by past experience. To this extent, strategic rather than extrapolative planning can become more useful.

Range of Alternatives and Outcomes - Another basic difference between strategic and extrapolative planning lies in the approach to considering possible alternatives and outcomes. In extrapolative planning, we start from a restricted set of alternatives and outcomes with last year's experiences having a preferred position. In manpower planning, a department tends to shape its faculty recruitment around past experiences. Thus, if you are a graduate of one of the top ten universities in the country, you are likely to get ten or fifteen offers from among the top twenty schools. The choice and selection process, though highly rational, is very restrictive. In strategic planning, a much larger set of choices is considered; there is an attempt to look beyond the past experiences to broaden the feasible alternatives and outcomes. For example, in faculty recruitment universities must now begin to look at the structure of faculties. New curricula addressing the needs of smaller communities require that we search for faculty members from Black, Mexican-American, Puerto Rican and other communities. The past cannot be fully extrapolated; we must examine a number of new alternatives and possible outcomes - developing faculty from existing pools of

manpower, recruitment of faculty from a larger group of schools, search and recruit among "underemployed" manpower, etc.

Ordering Relations - Assuming alternatives and outcomes can be specified, there is the additional task of ranking or ordering the planning possibilities implied by such a set. In extrapolative planning, the ranking reflects certain beliefs about the future that are based on past experience. On the basis of previous successes and failures, weights may be assigned to alternatives. If alternative I, for example, has a better chance of success, that alternative is given top priority. In strategic planning, such an ordering scheme may not be possible because there may be no previous examples or similar courses of action from which to infer. In the faculty recruitment example, a university may be guided by moral and social considerations to go beyond a manpower development plan which is likely to be successful. But how far to go in screening other alternatives cannot be answered except through search and experimentation as a first step, and given that experience make further changes. The ordering of alternatives is much more subjective and unstructured in strategic planning.

Goals - A final difference between strategic and extrapolative planning can be seen in the way that goals are handled in the planning process. Goals specified in extrapolative planning are slight variations of established goals pursued in previous periods. Changes in the academic plan to bring about the modernization of the university as perceived by students are interpreted as adding new courses or revisions within curricula designed to meet the current structure of goals. In strategic planning, new and broad variations in the

goal structure may be a major concern. If we seriously seek to modernize the university, the goals of the university cannot be above reexamination. For instance, the implications of substituting community action goals for research goals at various points in the present goal structure of the university is an alternative that should be explored. Strategic planning explicitly recognizes the dynamic nature of goals as well as means.

In summary, strategic planning starts with the assumption that the environment of the organization, decision maker, alternatives and outcomes, ordering of alternatives and outcomes, and goals are elements to be examined as fully as possible. The less we take as "given", the more creative and effective a planning process will be. The past provides only one of many possible ways of meeting the challenge of tomorrow. Extrapolative planning projects from the past giving such experiences a major role in determining plans for the future. (Exhibit A provides a schematic summary of the differences between the two planning approaches.)

Strategic planning refers to a class of decisions that defines purposes, develops objectives, provides direction and determines roles of an organization within its larger environment. Such decisions must almost always be made on the basis of limited information and sometimes in the context of absolute uncertainty. These are the decisions which place the greatest strains and stresses on planning in organizations. What should we do about faculty development? How shall we increase the support for intramurally funded research in face of the increased needs of community action programs? How should we respond internally to the possibility of change in the

EXHIBIT A

ASSUMPTIONS ABOUT KEY PROBLEM-SOLVING ELEMENTS
IN PLANNING APPROACHES: A COMPARISON

KEY PROBLEM-SOLVING ELEMENTS	STRATEGIC PLANNING	EXTRAPOLATIVE PLANNING
I. State of Nature	Assumes forces in environment - highly variable and hence stresses "search" over many possible states	Assumes past experience reduces uncertainty about behavior of environmental forces
II. Decision Maker	Assumes decision maker is bounded rationally by basic human qualities - he does not optimize; he is constrained by limited perceptions, etc.	Assumes decision maker is "delicately skillful in analyzing the whole of a problematic situation."
III. Alternatives and Outcomes	Feasible set of alternatives are not known and the past is only one alternative without preferred position	Feasible set of alternatives and outcomes well-known from past experiences
IV. Ordering of Alternatives and Outcomes	Assumes ordering of alternatives and outcomes is the result of "search", "trial and error", experimentation and subjective consideration	Assumes ordering of alternatives can be based on past success or failure with some degree of risk
V. Goals	Assumes goals are variables to be examined fully without serious restrictions from previous experiences	Assumes relevant goals should be variations of those most acceptable and workable in the past

State's financial picture? What would be the impact of decreased national support for Ph.D. programs and increased support for "social education?" These are critical questions for strategic planning in higher education. There are similar questions facing other types of educational organizations.

STRATEGIC PLANNING AND COMPUTER SIMULATION

Computer simulations are dynamic models that make it possible for planners to examine logical descriptions of organizational behavior over time.[9] Strategic planning problems are futuristic, time-oriented problems requiring an understanding of organizational behavior not yet observable. It follows, therefore, that computer simulations should be an important vehicle for strategic planning. Computer simulation enhances strategic planning along several lines. First of all, computer models permit planners to consider the large and complex system models required to provide realistic descriptions of behavior processes in organizations. Second, computer simulation models facilitate aggregation of behavioral processes. For example, if one develops separate models of, say, the History and English Departments, a model of the interactions and joint behaviors of the two departments may start with the department models as basic modules. And thirdly, computer models improve the quality of analysis because of the increased flow of data. In a matter of minutes, computers generate data that ordinarily would not be available for 25 years in a real system.

For the purposes of discussing the usefulness of computer simulations in educational planning, we may divide the types of simulations into four groups:[10]

1. Descriptive Simulation Studies of Existing Organizations
2. Intellective Simulation Studies
3. Normative Simulation Studies
4. Man-Machine Simulations

Each of these groups has relevance for certain types of planning problems. In the next section, we shall briefly discuss each group with reference to a particular educational planning problem.

APPLICATIONS OF COMPUTER SIMULATION IN EDUCATIONAL PLANNING: SOME SUGGESTIONS

Descriptive Simulations

The primary focus of descriptive simulations is to provide models of human systems that explain their behavior.[11] In the study of organizations, such simulations are used to test theories by comparing past behavior of real organizations with simulated behavior. On the basis of such comparisons, researchers can attempt to relate changes in planned behavior with changes in observed behavior. The hiring of faculty, for example, at a given point of time follows from the execution of certain decision rules designed to stimulate certain planned behaviors. A descriptive simulation may be useful in analyzing organizational behavior resulting from such manpower decision rules because of its ability to consider planned and actual behavior as it evolves through time. Let us pursue this idea further.

In planning faculty needs, a critical determinant of the actual pattern of faculty development is the set of decision rules followed by various departments in promoting faculty into tenure positions. I suggest that insight into such decision rules may be developed

from analyzing the behavior of a simulated model of several departments within a given university.[12] Such models, of course, must start with empirical investigation of the departments to be studied. From there the computer model is developed: decision rules are formulated and relations transforming such rules into behavior mechanisms in the model are defined and coded for the computer.

What can we analyze with such a model? It has been hypothesized that promotions, for instance, may be the result of interdepartmental pressures rather than decision rules within a given department. This is a testable hypothesis. A descriptive model of an organization may be extremely useful for examining such an hypothesis.[13]

Another example of the usefulness of descriptive simulation can be found in student course selection. What are the most significant factors influencing the development of an observed pattern of course offerings? Using a descriptive model, one might examine the impact of certain decision rules followed by students in course selection processes in relation to decision processes followed by department chairmen, registrars and participants in program planning.[14]

"Intellective" Simulation Studies

This type of computer model is likely to be less descriptive of the real organization and more of a caricature capturing the important organizational qualities deemed relevant by the analyst.[15] "Intellective" simulations may be used to examine "if" situations. "What if" the external world of the university decided that "social education" should have top priority instead of advanced graduate education (Ph.D. programs) in universities such as the University of

California? To examine such a question, one would need a model that is capable of simulating departmental, interdepartmental and intercampus decision processes; capable of including a range of variables that reflect sociological, economic and administrative considerations; and capable of studying interactions of behavioral processes over time. Traditional models using system analysis depending on known mathematical techniques would not be adequate for this task.[16] Only a complex computer model could facilitate such a study. I suggest that in the future such strategic questions as "social education" vs. "Ph.D.s" will have to be examined to define certain feasible paths of growth for higher education if the projection of the recent report of the National Science Foundation on the supply of Ph.D.s is reasonable. That report suggests that the priority assigned to developing Ph.D.s for college teaching is in need of reexamination.[17]

In a similar manner, I suggest that the Master Plan of Higher Education of the State needs revision to reflect the changing educational aspirations of lower income groups, many of whom are Black and Mexican-American in California. "What if" junior colleges were tied to certain state colleges and the University of California campuses in a consortium arrangement for a given region? Are there social and educational returns from such a scale of organization that would offset some of the economic considerations? Such questions can be explored in the context of a simulated educational system representing the essence of the desired consortium.[18] The use of "intellective" simulations has been explored more fully by the speaker elsewhere.

Normative Simulations[19]

Social scientists have used normative models for many years and the use of simulations to approach normative considerations is consistent with a logical pattern of development for the social sciences. Communication problems, social interaction patterns, hierarchical structures and implications of problem-solving strains and stresses for organizations were originally analyzed and studied through contrived laboratory models built around small groups.[20] Computer models make it possible to build models superior to those devised in small group laboratories.

The question of organization structure and the distribution of power in large organizations can be examined through the use of computer models.[21] In this connection, one might raise the question of "decentralization" vs. "centralization": sharing of decision-making, questions of autonomy, relationships between participants in authority roles, etc. With the capacity to construct very large scale models to represent what an organization "ought to be", the researcher is free to analyze a number of hypothetical questions.

Using a normative model of a firm, Bonini[22] demonstrated that pressures resulting from prescribed organizational standards (sales quotas, production standards, etc.) do influence the behavior of the participants in the firm. High costs, for instance, are assumed to be inconsistent with good profits in a firm. Bonini suggests that if an organization is "loose" (less of a tendency to induce pressures for conformity to standards), it is quite possible that performance and job satisfaction may improve so as to offset high costs per se and, hence, leave profits unharmed or improved.[23] If

we transfer this type of thinking to the local control of school districts, one might raise the question: are there gains in the overall performance of a school district resulting from improved community involvement that offset the suggested losses from a "decline in professional standards?" This is the type of question that can be analyzed in part using normative computer models.

Man-Machine Simulations

In this type of computer simulation, the computer framework involves the interaction between a human actor and a simulated environment.[24] The computer starts with the simulated behavior of an organization. The decision-maker or actor reacts or responds to changes in the behavior of the organization, and the behavior of the organization in turn responds to the decision of the human actor. These interactions may take place over an extended period of time. Frequently, the objective of such interactions between computers and man are to provide a training exercise for the decision maker. Such management games, man-machine simulations, have been used very extensively in industrial organizations.[25] I suggest that the management game could be used to train education administrators along several lines.

Computer gaming may improve the awareness of students to organizational roles. Some perspectives essential to decision making at various levels of an organization can only be developed through experience. Top-level administrative positions require a certain level of detachment from departments or limited departmental identity. A dean cannot view his function through the eyes of a department chairman. Differences in the roles of top vs. middle-level

administrative decision making can be demonstrated through decision making in management games. For example, the importance of planning as a managerial function will increase as one moves from the operating to the policy level, and students can have an opportunity to learn this in a man-machine simulation.

Another important aspect of administration that can be learned in the context of management games is the use of information in decision making.[26] The importance of certain critical attributes of information for decision-making purposes can be learned. For example, in the case of control decisions, data must be sensitive and timely. Information that may be useful to convey the status of operations - expenditures, grades at the end of semester, etc. - may not be very useful for control and evaluation purposes.

Another important contribution of management games results from the joint problem-solving activities.[27] The opportunity to work with other members of a peer group in problematic situations, the opportunity to discuss alternative approaches, and the opportunity to compare the effectiveness of analytical techniques appear to improve the analytical ability of participants in management games. In view of the lack of strong analytical orientations in the past and the increased need for such ability presently, the use of management games for students of education administration could be a very positive step toward developing better administrators.

In summary, the possible applications of computer simulation techniques in education planning are numerous. The computer as an aid to planning has been woefully underutilized. The use of complex

computer models, however, is not without limitation. The larger and more complex computer models are, the more difficult it is to ascertain functional relationships between changes in parameters, variables, and changes in performance of the simulated system.[27] Such difficulties are not insurmountable and should not be a restraint on our efforts to improve the planning capacity of educational organizations.

FOOTNOTES

1. For a thorough discussion of computer simulation, the following sources may be reviewed: Kalman J. Cohen and Richard M. Cyert, "Simulation of Organizational Behavior", in Handbook of Organizations, (Ed.) James G. March (Chicago: Rand McNally & Co., 1965); Kalman J. Cohen and Richard M. Cyert, "Computer Models in Dynamic Economics", Quarterly Journal of Economics, Vol. 75, No. 1, pp. 112-127; and Richard M. Cyert, "A Description and Evaluation of Some Firm Simulations", Proceedings of the IBM Scientific Computing Symposium on Simulation Models and Gaming, December 7-9, 1964, Thomas J. Watson Research Center, Yorktown Heights, New York.

2. Cyert, "A Description and Evaluation of Some Firm Simulations", Op. Cit., page 4.

3. For example, see Murray A. Geisler, "The Simulation of a Large Scale Military Activity", Management Science, Vol. V, No. 4, July, 1959; and Richard M. Cyert and James G. March, A Behavioral Theory of the Firm (Englewood Cliffs, N.J.: Prentice Hall, 1963).

4. H. Igor Ansoff, "The Evolution of Corporate Planning", Stanford Research Institute, September, 1967, pp. 4-8.

5. Ibid, p. 2.

6. The writer has used "Strategic" instead of "Entrepreneurial" on the basis of other work by Ansoff. See the following for a thorough discussion of strategic planning: H. Igor Ansoff, "A Quasi-Analytic Method of Long Range Planning", in Organizational Decision Making by Marcus Alexis and Charles Z. Wilson (Englewood Cliffs, N.J.: Prentice Hall, 1967) and H. Igor Ansoff, "A Quasi-Analytical Approach to Business Policy Problems", Management Technology, Vol. 4, No. 1 (June, 1964).

7. "Open" problem solving has been developed more fully in: Marcus Alexis and Charles Z. Wilson, Organizational Decision Making (Englewood Cliffs, N.J.: Prentice Hall, 1967).

8. Alexis and Wilson, Op. Cit., p. 149.

9. See Robert M. Rauner and Wilbur A. Steger, "Simulation and Long-Range Resource Allocations", Quarterly Journal of Economics, Vol. 52, May, 1962, pp. 219-245.

10. Cyert, Op. Cit., pp. 4-5.

11. See the following sources for more discussion of descriptive computer models: Kalman J. Cohen, "Simulation of the Firm", American Economic Review, Papers and Proceedings, Vol. 50,

May, 1960, pp. 534-40; Richard M. Cyert and James G. March, A Behavioral Theory of the Firm (Englewood Cliffs, N.J.: Prentice Hall, 1963); and Gary H. Orcutt, Martin Greenberger, Joan Korbel, and Alice M. Rivilin, Microanalysis of Socio-Economic Systems, (New York: Harper & Brothers, 1961).

12. Such a block-building approach to developing computer models has been attempted by Cyert and March, Op. Cit., and Orcutt et al, Op. Cit., in developing descriptive micro-systems.

13. Charles Z. Wilson, "Organizational Factors in Tax Shifting", Western Journal of Economics, Fall, 1965.

14. Research in this area has generally drawn on input-output models that entails rather broad generalization about the behavior of classes of students. For example, see Russell C. Koza, "The Use of Micro-Structural Input-Output Systems Analysis in Educational Resource Allocation Decision-Making", National Meeting of the Operations Research Society of America and The Institute of Management Sciences, May, 1968.

15. See Gordon B. Davis, Howard Ambill and Herbert Whitecroft, "Simulation of a Finance Company Operations for Decision Making", Management Technology, Vol. 3, May, 1963.

16. Cohen and Cyert, Quarterly Journal of Economics, Op. Cit., pp. 119-121, and Charles Z. Wilson, "Income Effects of the Corporate Income Tax Reconsidered", Bentley Business and Economic Review, Vol. IV, No. 3, June, 1968.

17. Science and Engineering Staff in Universities and Colleges, National Science Foundation, NSF 67-11 (Washington, D.C.: Superintendent of Documents, U.S. Government Printing Office, 1967).

18. Such simulation would center on interorganizational behavior in much the way that economists have focused on inter-firm phenomena.

19. The most successful normative simulation to date is by Charles P. Bonini, Simulation of Information and Decision Systems in the Firm (Englewood Cliffs, N.J.: Prentice Hall, 1963).

20. Karl E. Weick, "Laboratory Experimentation with Organization" in Handbook of Organizations (Ed.) James G. March, Op. Cit., pp. 194-260.

21. Richard M. Cyert and James G. March, "Organizational Factors in the Theory of Oligopoly", Quarterly Journal of Economics, Vol. 70, 1956, pp. 44-64.

22. Bonini, Op. Cit., pp. 103-134.

23. Ibid, pp. 132-133.

24. The most complex man-machine simulation involving the study of organizations was developed by the faculty of the Graduate School of Industrial Administration: The Carnegie Tech Management Game (Homewood, Ill: Richard D. Irwin, 1964).

25. Kalman J. Cohen and Eric Rhenmon, "The Role of Management Games in Education and Research", Management Science, Vol. VII, No. 2, January, 1961.

26. Kalman J. Cohen and Merton H. Miller, "Management Games, Information Processing and Control", Management International, Vol. 3, 1963.

27. James L. McKenny, "Evaluation of a Decision Simulation as a Learning Environment", Management Technology, Vol. 3, 1963.